SECTION 8
ECONOMIC ANALYSIS

This economic analysis presents cost estimates for using the Envirogen technology to treat contaminated ground water. Cost data were compiled during the demonstration at the NBVC, during the previous demonstration at a service station in New Jersey, and from Envirogen. The vendor claims that because the demonstration at the NBVC project involved the application of their technology at pilot-scale, it was not possible to evaluate the start-up costs based on data collected during the demonstration. Therefore, the start-up costs were reviewed and scaled accordingly based on team member's experience with full-scale remediation using related technologies (i.e., sparging and biostimulation) and lessons learned during the demonstration. This also is due, in part, because some of the demonstration's associated costs such as installation of the ground-water monitoring wells and plots survey were handled by EPA. As a National Environmental Technology Test Site (NETTS), NBVC was responsible for providing access to pre-characterization data. Furthermore, the ground-water sampling and routine operation and maintenance of the Envirogen system was performed in association with NBVC staff. NETTS supplied utilities, handled waste disposal, and assisted in site demobilization activities. EPA served as the interface between California Water Quality Board and the NBVC for the technical justification and preparation of the project permit, therefore, the permitting cost for Envirogen was reduced to attending a public hearing meeting.

This section describes a site, based on experience gained by Envirogen's previous demonstration at a gas station as well as that gained at the Port Hueneme field demonstration. These experiences were selected for economic analysis, summarized the major issues involved and assumptions made in performing the analysis, discussed costs associated with using the Envirogen propane biostimulation and bioaugmentation technology to treat ground-water contaminated with MTBE, and presented a conclusions of the economic analysis.

8.1 INTRODUCTION

The vendor operated a system consisting of a network of oxygen, bacteria, and propane injection points, pressurized oxygen and propane gas delivery and control systems, and ground-water and soil-gas monitoring network. However, the vendor claims the system could operate with slight modifications at a larger or smaller scale; therefore, the economic analysis presents and evaluates costs based on an

application involving the treatment of contaminated ground water at a typical gas station site. Table 8-1 summarizes estimated costs as determined by Envirogen.

8.2 APPLICATION ISSUES AND ASSUMPTIONS

Typically, costs are placed in 12 categories applicable to typical cleanup activities at Superfund and RCRA sites (Evans 1990). These categories include: (1) site preparation, (2) permitting and regulatory, (3) mobilization and startup, (4) equipment, (5) labor, (6) supplies, (7) utilities, (8) effluent treatment and disposal, (9) residual waste shipping and handling, (10) analytical services, (11) equipment maintenance, and (12) site demobilization. Even with a detailed analysis, costs are considered to be order-of-magnitude estimates with an expected accuracy of from 30 - 50 percent above to 30 -50 percent below actual costs. Therefore, for this economic analysis, the categories applicable to hazardous waste sites are recognized and discussed. In the event that a determination of a distinct cost associated for each of the categories was not possible due to the special circumstances of this project (see Section 8), an attempt was made to provide an estimated cost at the hazardous waste sites. However, based on Envirogen's past performance, this section also describes the case of "a typical gas station" selected for economic analysis, summarizes the major issues involved and assumptions made in performing the analysis, discusses costs associated with using the Envirogen technology to treat ground-water contaminated with MTBE, and presents the conclusions of the economic analysis.

This section lists the major assumptions, site-specific factors, equipment and operating parameters, and financial calculations used in this economic analysis of the Envirogen technology. Issues and assumptions are presented in Sections 8.2.1 through 8.2.3. Certain assumptions were made to account for variable site and waste parameters. Other assumptions were made to simplify cost estimating for situations that actually would require complex engineering or financial functions. Section 8.2.3 provides a hypothetical base-case scenario developed from the assumptions. In general, Envirogen system operating issues and assumptions are based on information provided by Envirogen and observations made during the demonstration.

TABLE 8-1
Estimated Cost for Envirogen Propane Biostimulation and Bioaugmentation Project at a Typical Gas Station

Activity	Event No.	Labor	Pass Through	Subcontracted Equipment	Materials	Total
Design	1	$ 21,700	$ -	$ -	$ -	$ 21,700
Procurement and Mobilization	1	$ 19,540	$ 120	$ 2,625	$ -	$ 22,285
Installation	1	$ 31,660	$ 1,350	$ 15,015	$ 1,815	$ 49,840
Baseline Monitoring	1	$ 1,400	$ 1,550	$ 1,208	$ -	$ 4,158
Startup	1	$ 4,360	$ 480	$ -	$ -	$ 4,840
O&M and Quarterly Monitoring	8	$ 6,135	$ 2,005	$ 53	$ 28	$ 65,760
Utilities Including Electric and Propane/ Quarter	8		$ 430			$ 3,440
Demobilization	1	$ 3,325	$ 300	$ -	$ -	$ 3,625
Final Report	1	$ 1,605	$ -	$ -	$ -	$ 1,605
Total*						**$ 177,253**

Abbreviation:

O&M: Operation and Maintenance

Note:

***:** Total estimate for remediation cost is based upon 2 years of operation.

1. The cost of oxygen is not provided in Table 8-1.
2. Design cost includes design and drawings, discharge permit application, and attending one meeting.
3. Procurement and mobilization include equipment and materials procurement, mobilization preparation, and mobilization.
4. Installation cost includes subcontractors' labor, materials, and equipment for site work including air sparging points, monitoring wells, trenching, and pipe installation, backfilling and surface restoration, system and electrical connection.
5. Baselines monitoring includes sampling 4 wells and VOC analysis.
6. Startup cost is based on three days of monitoring and a letter report.
7. Quarterly monitoring includes sampling 4 wells and VOC analysis and a letter report.
8. Demobilization includes disconnection, dismantling, and system removal from site.
9. Final report includes final letter report prepared and submitted to client.

8.2.1 Site-Specific Factors

Site-specific factors can affect the costs of using the Envirogen treatment system. These factors can be divided into the following two categories: waste-related factors and site features. Waste-related factors affecting costs include waste volume, contaminant types and levels, treatment goals, and regulatory requirements. Waste volumes affect total project duration and, consequently, costs because a larger volume takes longer to treat. However, economies of scale are realized with a larger-volume project when the fixed costs are distributed over the larger volume. The contaminant types and levels in the ground water and the treatment goals for the site determine (1) the appropriate Envirogen treatment system size, which affects capital equipment costs , and (2) periodic sampling requirements, which affect analytical costs. Regulatory requirements affect permitting costs and sampling as well as the ground-water monitoring costs. Site features affecting costs include ground-water recharge rates, ground-water chemistry, site accessibility, availability of utilities, and geographic location. Ground-water recharge rates affect the time required for cleanup. Site accessibility, availability of utilities, and site location and size all affect site preparation costs. Site-specific assumptions include the following:

1. The site is a located near an urban area. As a result, utilities and other infrastructure features (for example, access roads to the site) are readily available.

2. The site is located in a region that has relatively mild temperatures during the winter months resulting in potentially high bacterial metabolism.

3. Contaminated ground water is located in a shallow aquifer.

8.2.2 Equipment and Operating Parameters

The Envirogen biostimulation system can be used to treat shallow ground water contaminated with MTBE. This analysis provides costs for treating contaminated ground water. Envirogen will provide the appropriate system configuration based on site specific conditions, of which ground-water recharge rates and contaminant concentration are the primary considerations. The Envirogen system can be configured to meet certain site requirements by varying the sparge systems, which are also dependent on site conditions. The Envirogen system is modular in design, which allows for treatment units either in series or in parallel to treat ground water. This analysis focuses on the estimated costs associated with the unit demonstrated at the NBVC Site. The vendor claims that their system can treat ground water contaminated with BTEX/MTBE concentration in the source area at 60 mg/L with the maximum contaminant being MTBE. The system operates on a continuous cycle, 24 hours per day, 7 days per week.

Based on these assumptions, this analysis assumes that about 81,000 gallons of water need to be treated to complete the ground-water remediation project, which will take about 2 years to process. It is difficult in practice to determine both the volume of ground water to treat and the actual duration of a project, but these figures have been assumed to perform this economic analysis.

As expected in a full operation, neither depreciation nor salvage value is applied to the costs presented in this analysis because the equipment is not purchased by a customer. All depreciation and salvage value is assumed to be incurred by Envirogen and is reflected in the ultimate cost. Equipment and operating parameter assumptions are listed below.

1. The treatment system is operated 24 hours per day, 7 days per week, 52 weeks per year;
2. The treatment system operates automatically without constant attention of an operator;
3. Modular components consisting of the equipment needed to meet potential treatment goals are mobilized to the site and assembled by Envirogen;
4. Air emissions monitoring is necessary; and
5. Envirogen equipment will be maintained by Envirogen and will last for the duration of the ground-water treatment project with proper maintenance.

Specifically, Envirogen claims that operation and maintenance costs shown in Table 8-1 are based on typical monitoring requirements including:

1. Personnel training required to operate, maintain, and monitor the system;
2. Analytical costs;
3. Routine maintenance;
4. Waste handling and disposal; and
5. Utilities.

Envirogen believes that no specialized training costs are associated with the operation, maintenance, and monitoring of this type of system. An understanding of system operation and the importance of vapor monitoring results as they apply to fugitive VOC and propane emission is required. Analytical costs for MTBE analysis would not increase for the typical gas station site at which regular VOC analysis is constructed, as MTBE is included in the standard VOC scan. Additional analytical costs might include

analysis for TBA, dissolved carbon dioxide, and propane. Bacterial analyses may be required at some sites, with associated additional costs, particularly at sites where bioaugmentation is performed. Routine system maintenance, including that necessary to prevent silting and clogging of wells, is similar to that required for a typical air sparge system at a comparable cost. The labor costs for sampling and monitoring activities would be slightly higher than those for a standard monitoring program, because low-flow ground-water sampling methods would be employed.

8.2.3 Base-Case Scenario

A hypothetical base-case scenario has been developed using the issues and assumptions described above for the purposes of formulating this economic analysis. Although the system under this evaluation was not a portable unit, the costs presented are for an Envirogen system for the remediation of contaminated ground water at a typical gas station. Thus, the following assumptions are made by Envirogen for the gas station remediation.

1. The service station area is 100 feet. x 60 feet. with the remediation area measuring 60 x 60 ft.
2. The subsurface soil is a medium sand with a porosity of 0.3 and the depth to ground water is 10 ft. below grade (bg).
3. The vertical extent of ground water contamination is 10 feet. below the ground water. Thus, the volume of ground water to be treated is 81,000 gal. The volume of saturated contaminated soil is 1330 yd^3.
4. The BTEX/MTBE concentration in the ground water in the source area is 60 ppm with the maximum contaminant being MTBE.

Envirogen made additional assumptions for the installation, operation, and maintenance of their biostimulation system:

1. 6 air sparging/propane injection points installed to 10 feet. below ground water.
2. 4 monitoring wells installed to 10 ft. below ground water.
3. 4 monitoring points installed to 1 foot. above ground water.
4. Estimated 200 feet. of piping to injection points installed below grade.

5. Biostimulation system trailer with air sparging blower, propane tank, piping, instrumentation and control panel. The tasks for implementing the design, installation, and operation and maintenance of the system with a description of the subtasks with their associated costs are provided in Table 8-1.

Envirogen claims that the total cost is based on the time needed to remediate the ground water to a cleanup objective of 70 μg/L. The time to remediate the ground water to the cleanup objective is estimated to be two years which was derived from degradation rates from other sites. Based on a two-year remediation, the total cost for the project is estimated to be $177,000 +/- 20%. Envirogen stated that at a volume of contaminated ground water of 81,000 gallons, the unit cost to remediate this medium is $2.35/gal. Further assumptions used for this base-case scenario are listed below.

- The air sparging will operate four times a day at 0.5 hour each time for a total operating time of 2 hours/day.
- The site is near Envirogen's office and travel cost and per diems are not needed.
- If bacterial injection is needed, the additional cost is $1000 per event.
- The biostimulation system will be leased to the project.

8.3 COST CATEGORIES

Table 8-1 presents cost breakdowns as provided by Envirogen addressing the various cost categories. Cost data associated with the MTBE demonstration program and hazardous waste sites have been presented for the following categories: (1) site preparation, (2) permitting and regulatory, (3) mobilization and startup, (4) equipment, (5) labor, (6) supplies, (7) utilities, (8) effluent treatment and disposal, (9) residual waste shipping and handling, (10) analytical services, (11) equipment maintenance, and (12) site demobilization. Each of these cost categories is discussed below.

8.3.1 Site Preparation Costs

Site preparation costs include administrative, treatment area preparation, treatability study, and system design costs. Site preparation administrative costs, such as costs for legal searches, access rights, and site planning activities, are usually estimated to be $35,000.

The treatment area preparation includes constructing a shelter building or purchasing a pre-manufactured shed for the housing of the air sparging blower, propane tank, piping, instrumentation and control panel. The shelter building needs to be constructed before mobilization of the technology system.

A building with a minimum of 200-square-foot is required for the system. Vendor will provide the shelter building design specifications. Construction costs will be varied based on the geographic location and the need for installation of heating and cooling system. Construction cost for building a shelter is estimated to be $90 per square foot, with a natural gas heating and cooling unit and ductwork costing about $10,000 installed. The total shelter building construction cost system is estimated to be $28,000.
This analysis assumes that monitoring wells exist on site and are located 200 feet from the shelter building. The total costs, including all electrical equipment and installation (air sparging blower and instrumentation and control panel), are $7,000. Piping and valve connection costs are about $20 per foot, which covers underground installation. Therefore, the total piping costs are $4,000. The total treatment area preparation costs are estimated to be $74,000.

A treatability study and system design will be conducted by the vendor to determine the appropriate treatment system. It is assumed that the vendor will transport its mobile system to the site to test the equipment under site conditions. Six to eight samples will be collected from the influent and effluent and will be analyzed off site for VOCs. The estimated treatability study cost is $15,000, including labor and equipment costs. System design includes determining the size and configuration of the system to achieve treatment goals and designing the configuration. The system design is estimated to cost $5,000. Total site preparation costs are, therefore, estimated to be $94,000.

8.3.2 Permitting and Regulatory Costs

Permitting and regulatory costs depend on whether treatment is performed at a Superfund or a RCRA corrective action site and on how treated water and any solid wastes are disposed. Superfund site remedial actions must be consistent with all applicable environmental laws, ordinances, regulations, and statutes, including federal, state, and local standards and criteria. Remediation at RCRA corrective action sites requires additional monitoring and record keeping, which can increase the base regulatory costs. In general, applicable or relevant and appropriate requirements (ARARs) must be determined on a site-specific basis. The cost of this permit would be based on regulatory agency requirements and treatment goals for a particular site. The discharge permit is estimated to cost $5,000.

8.3.3 Mobilization and Startup Costs

Mobilization and startup costs include the costs of transporting the system to the site, assembling the system, and performing the initial shakedown of the treatment system. The vendor provides trained personnel to assemble and conduct preliminary tests on the system. The vendor personnel are trained in health and safety procedures, so health and safety training costs may not be included as a direct startup cost. Initial operator training is needed to ensure safe, economical, and efficient operation of the system. The vendor provides initial operator training to its clients as part of providing the system. Transportation costs are site-specific and vary depending on the location of the site in relation to the system. For this analysis, the system is assumed to be transported 1,000 miles. The vendor retains the services of a cartage company to transport all of their treatment system equipment. Mobilization costs are about $10 per mile, for a total cost of $10,000. The costs of highway permits for overweight vehicles are included in this total cost. Assembly costs include the costs of unloading equipment from the trailers, assembling the system, hooking up well piping, and hooking up electrical lines. A two-person crew will work three 8-hour days to unload and assemble the system and perform the initial shakedown. The total startup costs are about $10,000, including labor and hookup costs. Total mobilization and startup costs are therefore estimated to be $20,000.

Specifically, for the purpose of this economic analysis, as described previously in the Section 8.0, the startup costs were reviewed and scaled accordingly based on Envirogen team member's experience with full-scale remediation using related technologies (i.e., sparging and biostimulation) and lessons learned during the NBVC demonstration. Each of the costs is site-specific and will vary according to the degree of design and installation required. Startup costs that were evaluated include the following:

1. System design and work plan preparation;
2. Permitting and regulatory approval;
3. Well installation costs including air sparge points and monitoring wells; and
4 Capital equipment costs including system components, and monitoring equipment, and well installation costs are not applicable if an existing system (e.g., an air sparge system) is being retrofitted to include propane injection and bioaugmentation. In that case, existing monitoring wells would be used, and existing air sparge points could be used for substrate and bacterial injection. According to Envirogen, capital equipment costs for system components associated with retrofitting an existing system are minimal.

Envirogen further claims that in any propane biostimulation system, very little propane is required, with typical feed rates of less than 0.3 pounds of propane per day. When coupled with air or oxygen injection, the need for vapor extraction is typically eliminated, although the need for this contingency is site-specific. If a vapor extraction system is required, the cost for a standard SVE system would apply.

8.3.4 Equipment Costs

Envirogen provides the complete Envirogen treatment system configured for site-specific conditions. All Envirogen treatment equipment is leased to the client. As a result, all depreciation and salvage value is incurred by Envirogen and is reflected in the price for leasing the equipment. At the end of a treatment project, Envirogen decontaminates and demobilizes its treatment equipment (see Section 8.3.12, Site Demobilization Costs). Envirogen assumes that this equipment will operate for the duration of the ground-water remediation project and will still function after the remediation is complete as a result of routine maintenance and modifications. Equipment costs are determined by the size of the Envirogen system needed to complete the remediation project and are incurred as a lump sum; as a result, even though the equipment is leased to the client, it is not priced at a monthly rate. For this analysis, Envirogen estimates that the base capital equipment costs is $10,000 for a system employed at a typical gas station.

8.3.5 Labor Costs

Once the system is functioning, it is assumed to operate continuously except during routine maintenance, which the vendor conducts (see Section 8.3.11, Equipment Maintenance Costs). One operator trained by the vendor performs routine equipment monitoring and sampling activities. Under normal operating conditions, an operator is required to monitor the system about once each week. This analysis assumes that the work is conducted by a full-time employee of the site owner and is assigned to be the primary operator to perform system monitoring and sampling duties. Further, it is assumed that a second person, also employed by the site owner, will be trained to act as a backup to the primary operator. Based on observations made at the demonstration, it is estimated that operation of the system requires about 8 hours per week of the primary operator's time. Assuming that the primary operator's burden labor rate is $50 per hour, the total annual labor cost is estimated to be $20,800.

8.3.6 Supply Costs

Except for oxygen, propane, and bacteria, no other chemicals or treatment additives are expected to be needed to treat the ground water using the technology. Supplies that will be needed as part of the overall ground-water remediation project include Level D, disposable personal protective equipment (PPE), PPE disposal drums, and sampling and field analytical supplies. Disposable PPE typically consists of latex inner gloves, nitride outer gloves, and safety glasses. This PPE is needed during periodic sampling activities. Disposable PPE is assumed to cost about $600 per year for the primary operator.
Used PPE is assumed to be hazardous and needs to be disposed of in 24-gallon, fiber drums. One drum is assumed to be filled every 2 months, and each drum costs about $12. The total annual drum cost is, therefore, about $100.

Sampling supplies consist of sample bottles and containers, ice, labels, shipping containers, and laboratory forms for off-site analyses. For routine monitoring, laboratory glassware is also needed. The numbers and types of sampling supplies needed are based on the analyses to be performed. Costs for laboratory analyses are presented in Section 8.3.10. The sampling supply costs are estimated to be $1,000 per year. Total annual supply costs are estimated to be $1,700.

8.3.7 Utility Costs

Electricity is the only utility used by the Envirogen system. Electricity is used to run the Envirogen treatment system. This analysis assumes that electrical power lines are available at the site. Electricity costs can vary considerably depending on the geographical location of the site and local utility rates. Also, the consumption of electricity varies depending on the Envirogen system used, the total number of air sparging units and other electrical equipment operating. This analysis assumes a constant rate of electricity consumption based on the electrical requirements of the Envirogen treatment system.

For the demonstration at Port Hueneme, the Envirogen control panel system that utilized 110 volt power was mounted on a portable, unitrust assembly that was anchored on an exterior wall of the U.S. EPA shelter building. The demonstration system power was supplied by NETTS. The total annual electrical energy consumption provided by Envirogen was based on their project at a gas station in New Jersey with the total annual electricity costs are therefore estimated to be about $ 6,276.

Water and natural gas usage are highly site specific but assumed to be minimal for this analysis. As a result, no costs for these utilities are presented.

8.3.8 Effluent Treatment and Disposal Costs

Depending on the degree to which treatment goals for a site were met, additional effluent treatment may be required, and thus additional treatment or disposal costs may be incurred. Because of the uncertainty associated with additional treatment or disposal costs, this analysis does not include effluent treatment or disposal costs.

The Envirogen system requires air monitoring because of the application of propane as a treatment substrate. As a result, additional air emission control may be required, and thus additional treatment or disposal costs may be incurred. Because of the uncertainty associated with additional treatment costs, this analysis does not include effluent treatment costs.

However, it is assumed that effluent monitoring (ground water leaving the treatment zone) and the air emission at the vapor monitoring and the ground water points are routinely conducted by the primary operator.

8.3.9 Residual Waste Shipping and Handling Costs

The only residuals produced during a successful propane biostimulation and bioaugmentation system operation are fiber drums containing used PPE and waste sampling and field analytical supplies, all of which are typically associated with a ground-water project. This waste is assumed to be hazardous and requires disposal at a permitted facility. This analysis assumes that about six drums of waste are disposed of annually. The cost of handling and transporting the drums and disposing of them at a hazardous waste disposal facility is about $1,000 per drum. The total drum disposal costs are, therefore, about $6,000 per year.

8.3.10 Analytical Services Costs

Required sampling frequencies are highly site specific and are based on treatment goals and contaminant concentrations. Analytical costs associated with a ground-water treatment project include the costs of laboratory analyses, data reduction, and QA/QC. This analysis assumes that one sample of untreated (upgradient) water, one sample of treated water (downgradient), and associated QC samples (trip blanks,

field duplicates, and matrix spike/matrix spike duplicates) will be analyzed for VOCs every month. Monthly analytical costs are estimated at $1,500. The total annual analytical costs are, therefore, estimated to be $18,000.

8.3.11 Equipment Maintenance Costs

Typically, annual equipment maintenance costs are estimated to about 3% of the capital equipment costs.

8.3.12 Site Demobilization Costs

Site demobilization includes treatment system shutdown, disassembly, and decontamination; site cleanup and restoration; utility disconnection; and transportation of the equipment off site. A two-person crew will work about five 8-hour days to disassemble and load the system. This analysis assumes that the equipment will be transported 1,000 miles either for storage or to the next job site. Generally, it is estimated that the total cost of demobilization is about $15,000. This total includes all labor, material, and transportation costs.

According to Table 8-1, the vendor stated that demobilization costs were minimal due to the proximity of the demonstration site to Envirogen's office. Elements of demobilization could include the following:

1. Labor associated with equipment decommissioning and removal;
2. Demobilization of staff;
3. Subcontractor costs associated with abandonment of demonstration wells;
4. Removal of above-grade distributions lines and equipment; and
5. Site restoration.

Equipment decommissioning and removal and demobilization of staff at the NBVC demonstration site was accomplished in one-half day due to assistance from NBVC staff and would not be expected to exceed 3 days at the full scale.

8.4 CONCLUSIONS OF ECONOMIC ANALYSIS

This analysis presents cost estimates for treating contaminated ground water with the Envirogen treatment system at pilot scale for a typical gas station. Table 8-1 presents the total cost as provided by Envirogen

for each cost category. Permitting and regulatory costs are not representative because they represent less than the normal costs. In addition, Effluent Treatment and Disposal Costs are not included in Table 8-1, since there are no cost estimates for this category. With Envirogen's assumptions (Section 8.2.3), the total cost to treat 81,000 gallons of contaminated ground water was estimated to be $2.35 per gallon.

In parallel to a cost estimate for a typical gas station, a cost estimate for the field demonstration at hazardous waste sites was presented. According to this analysis, one time costs (fixed costs) include site preparation, permitting and regulatory, mobilization and startup, equipment, and site demobilization. Annual costs include labor, supplies, utilities, effluent treatment and disposal, residual waste shipping and handling, analytical services, and equipment maintenance. This analysis of the technology shows that operating costs are strongly affected by the site specific environment, size and configuration of the vendor system, distance from the Envirogen office location with most of the annual costs per gallon being proportionally higher than estimated during this cost analysis, as presented in Table 8-1.